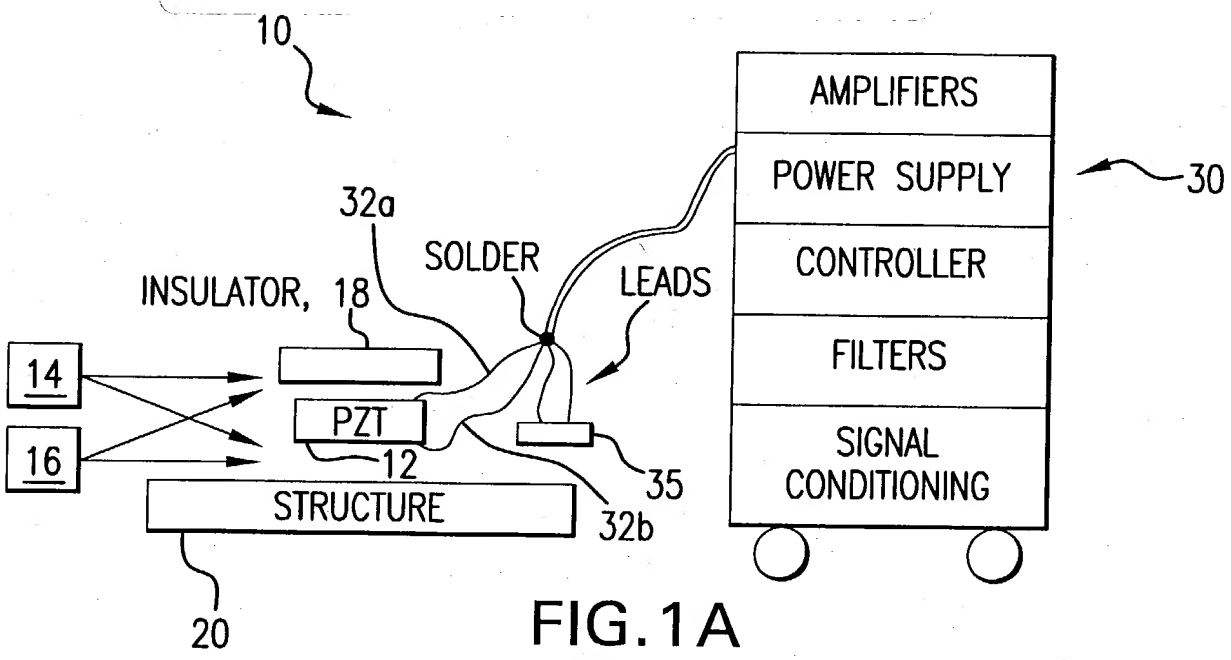


FIG.1A
PRIOR ART

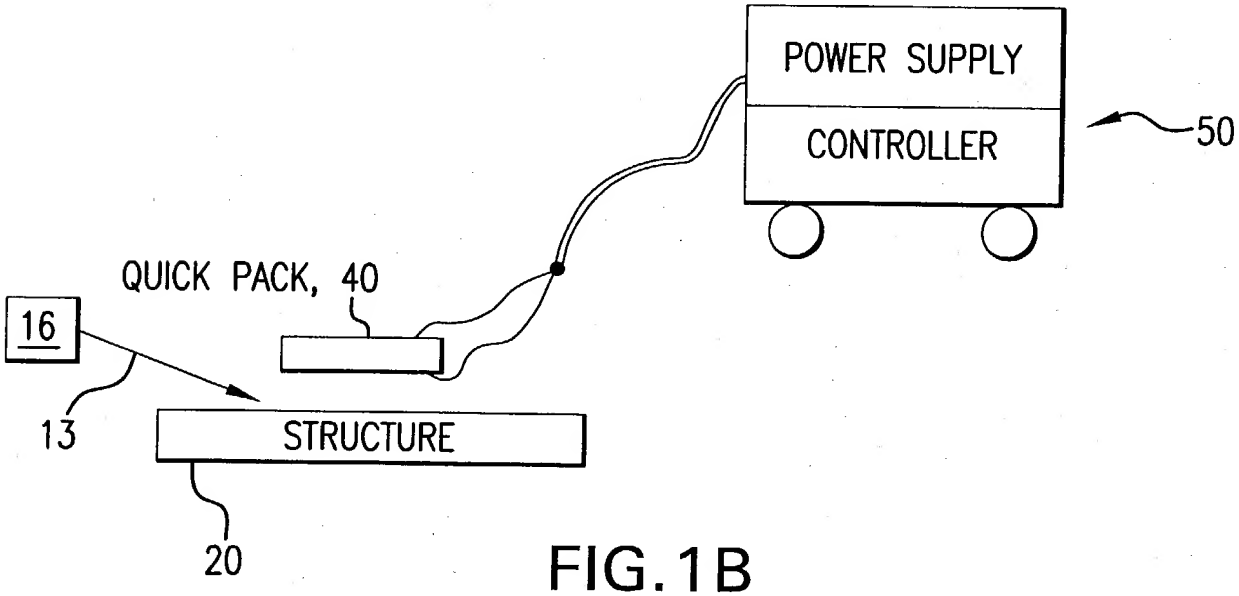


FIG.1B

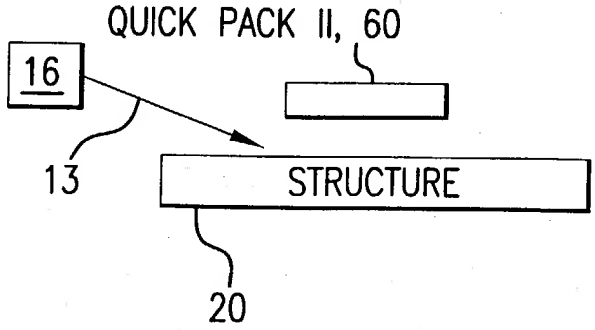


FIG.1C

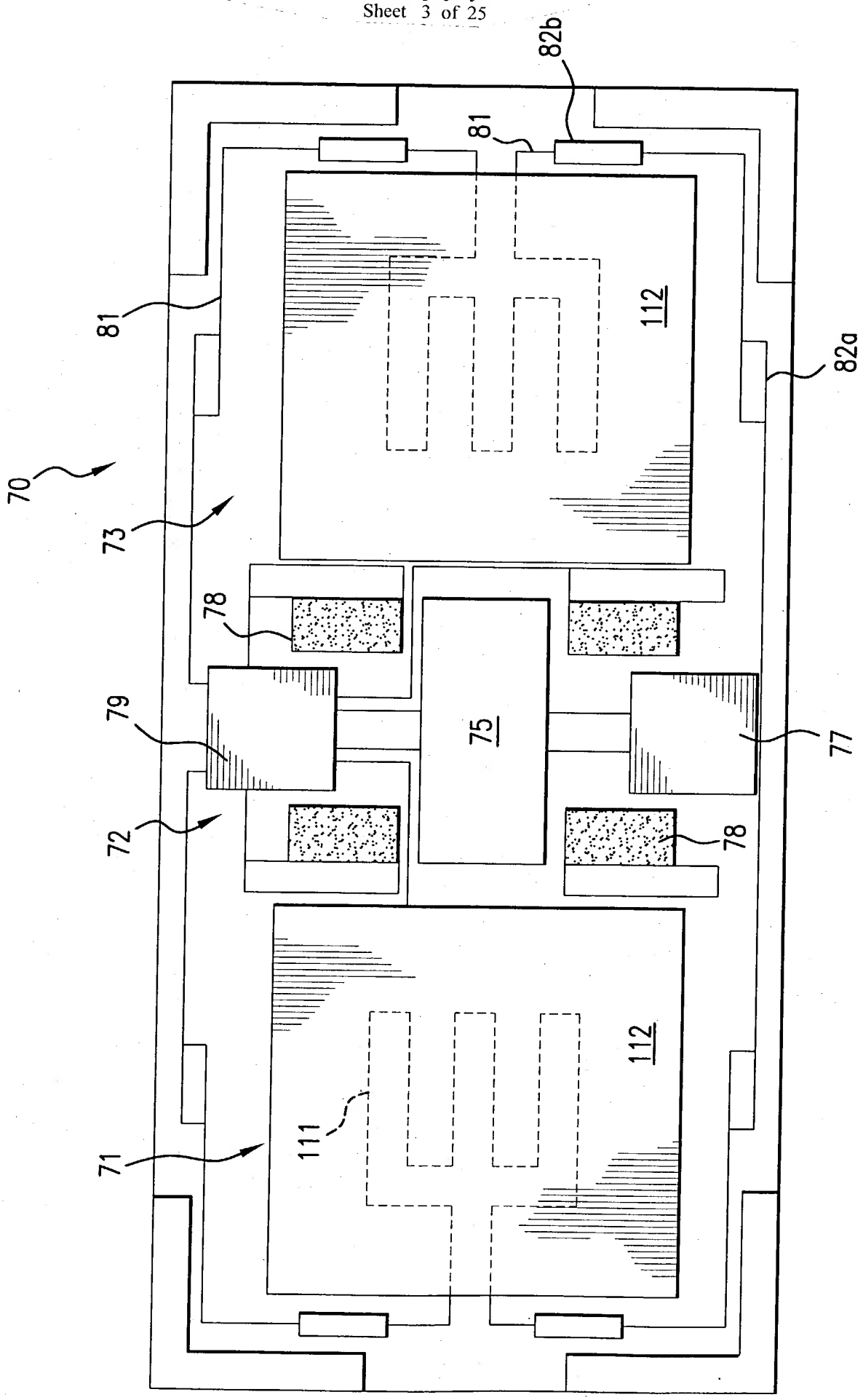


FIG.2C

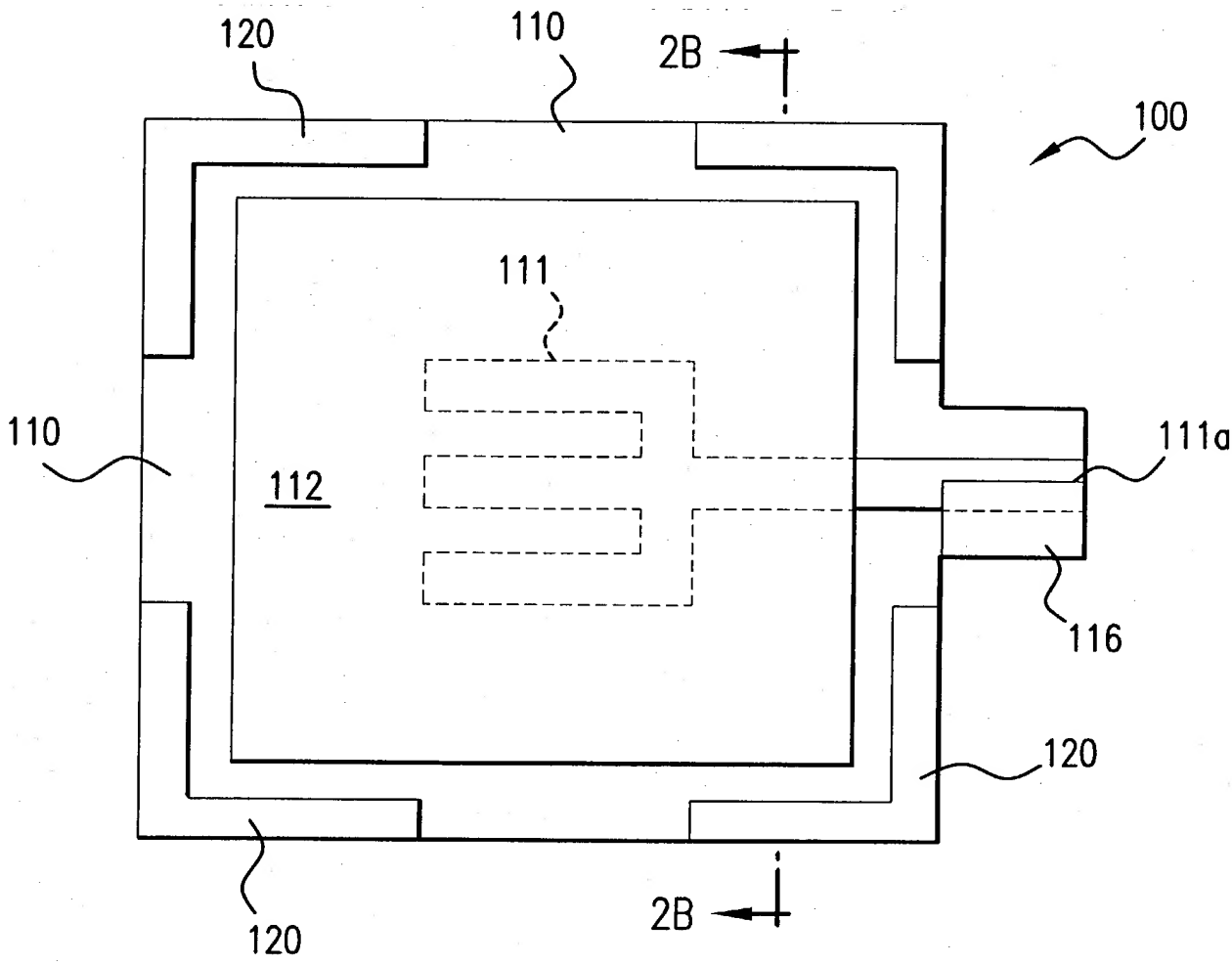

120
110
2B
100
111
110
112
111a
116
120
120
2B

FIG.2A

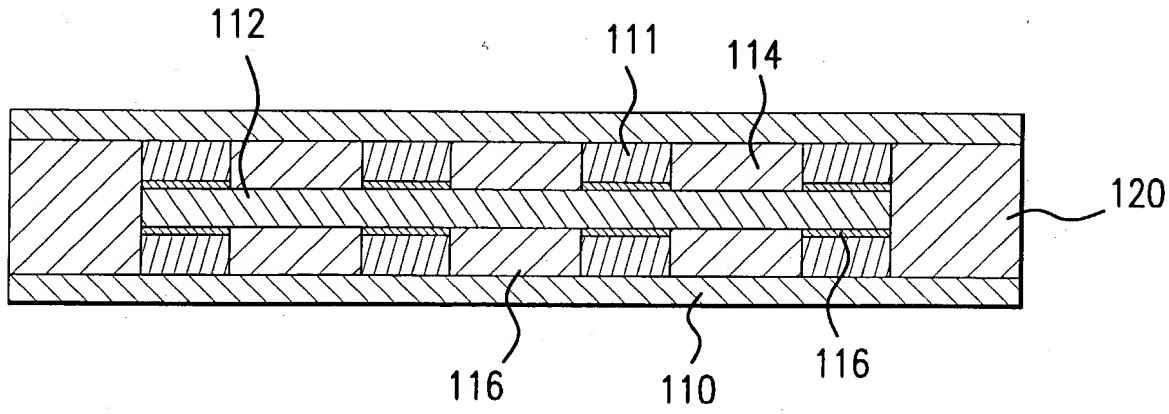

112
111
114
120
116
110
116

FIG.2B

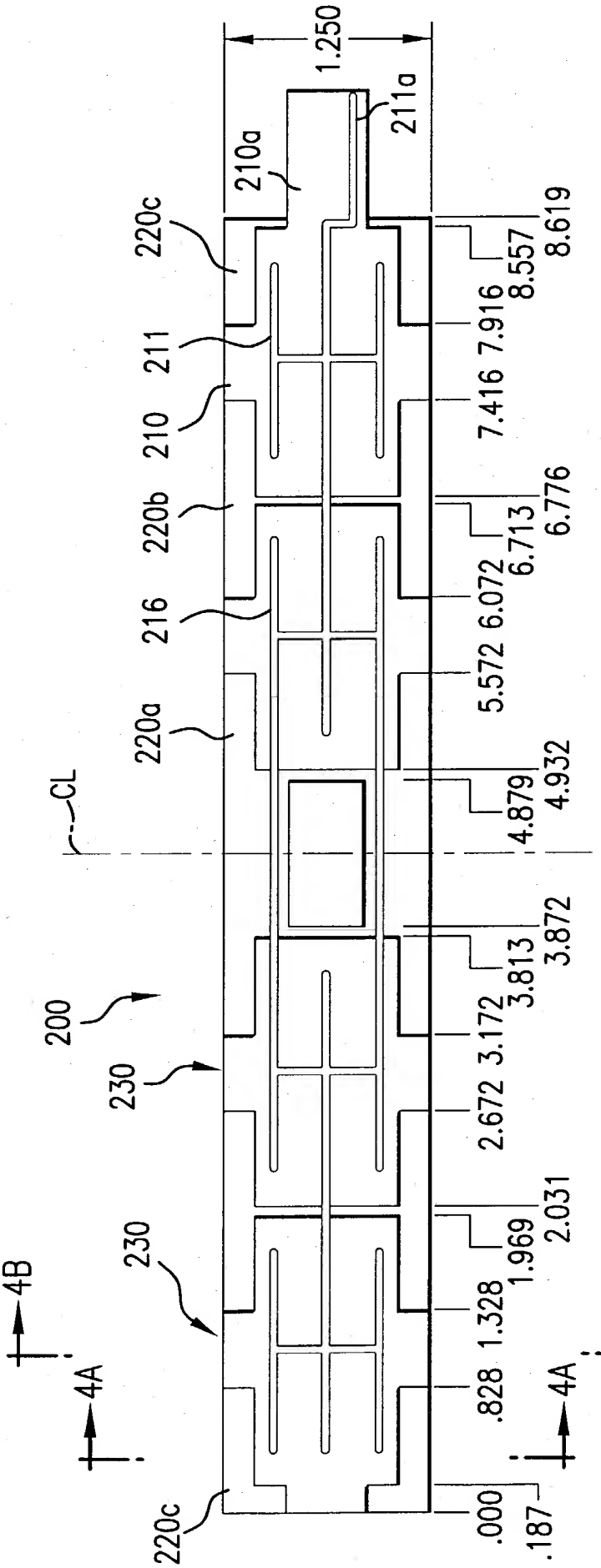

1.250
211a
210a
220c
211
210
220b
216
220a
CL
200
230
230
220c
4B
4A
4A
4B
8.619
8.557
7.916
7.416
6.776
6.713
6.072
5.572
4.932
4.879
3.872
3.813
3.172
2.672
2.031
1.969
1.328
.828
.187
.000

FIG. 3

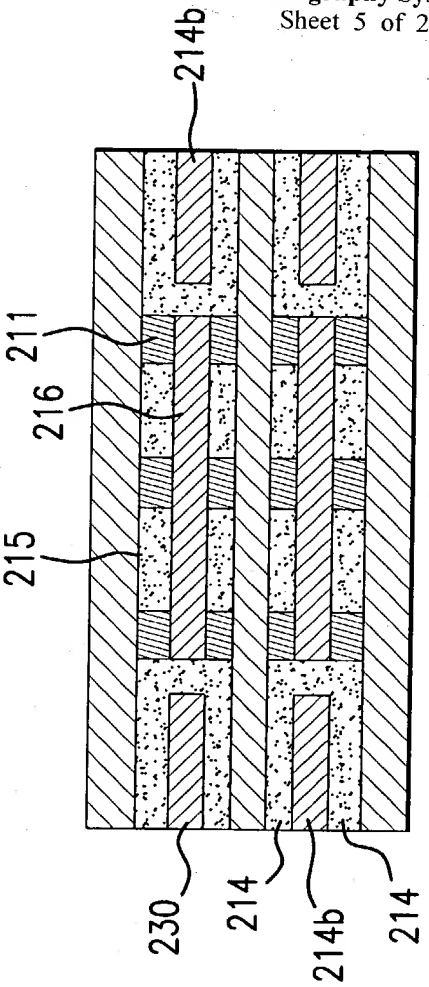

214b
211
216
215
230
214
214b
214

FIG.4B

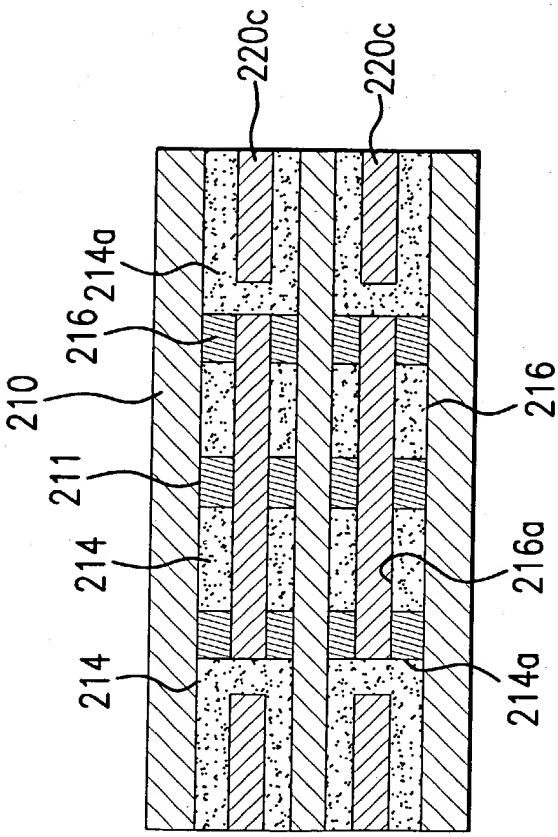

220c
220c
214a
216
210
211
214
214
216a
214a
216

FIG.4A

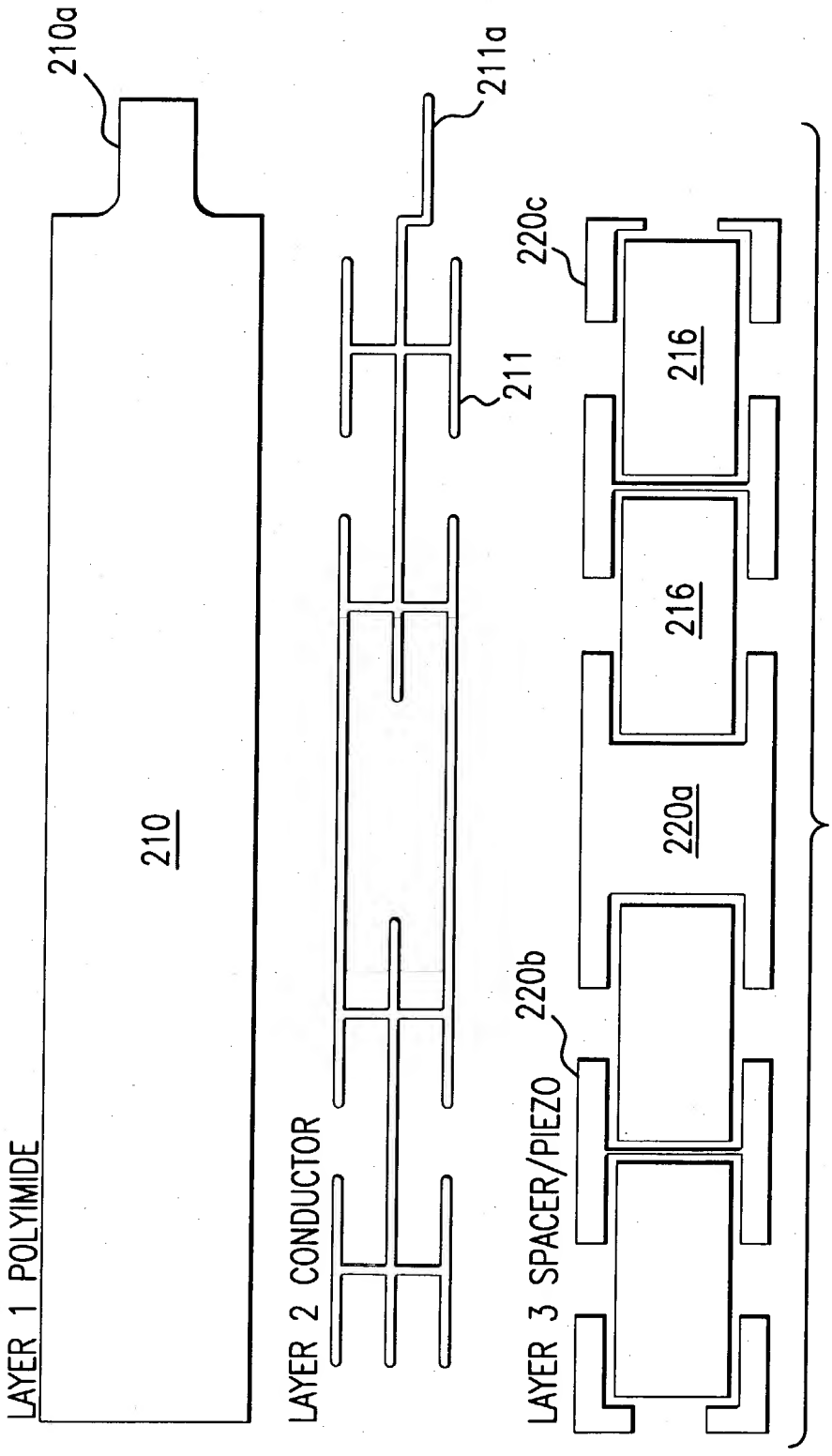

LAYER 1 POLYIMIDE
LAYER 2 CONDUCTOR
LAYER 3 SPACER/PIEZO
210a
210
211a
211
220c
216
216
220a
220b

FIG.5

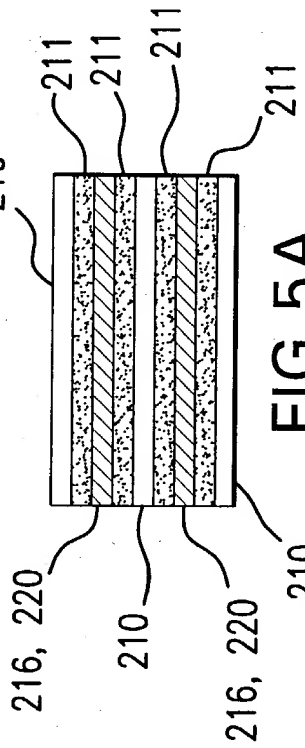

211
211
211
211
210
216, 220
210
216, 220
210

FIG.5A

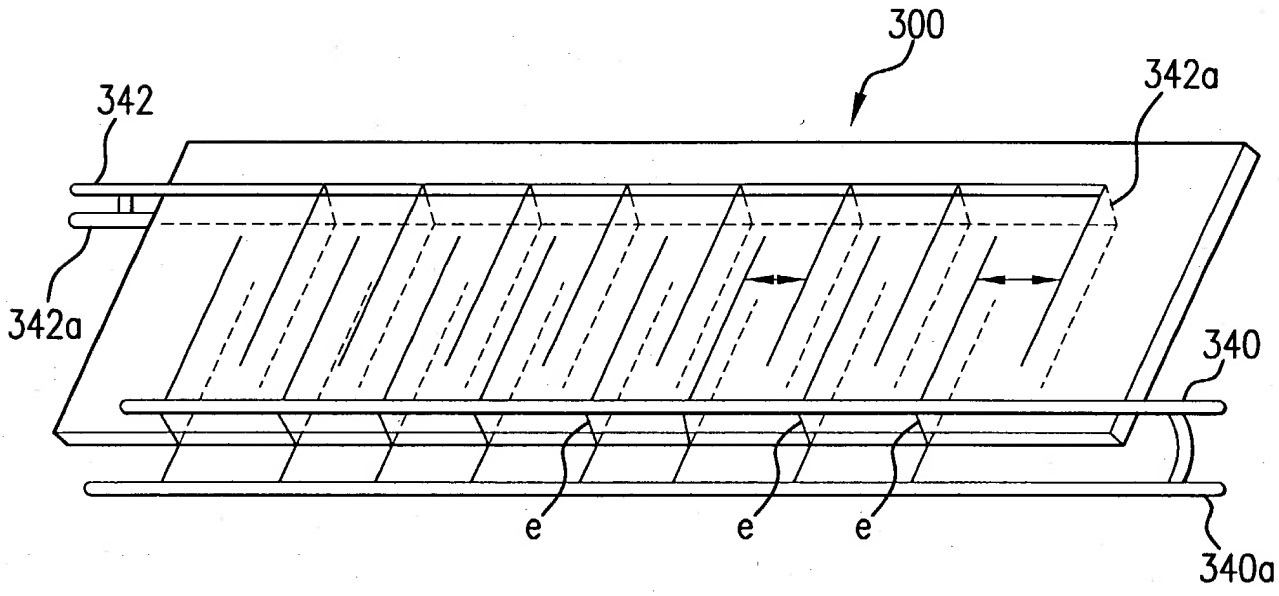


FIG.6

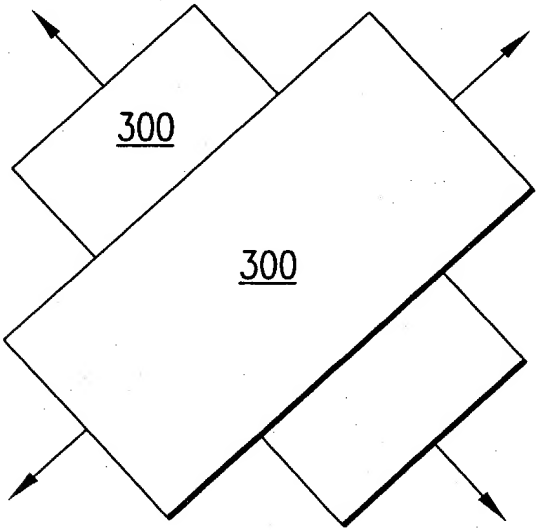


FIG.7

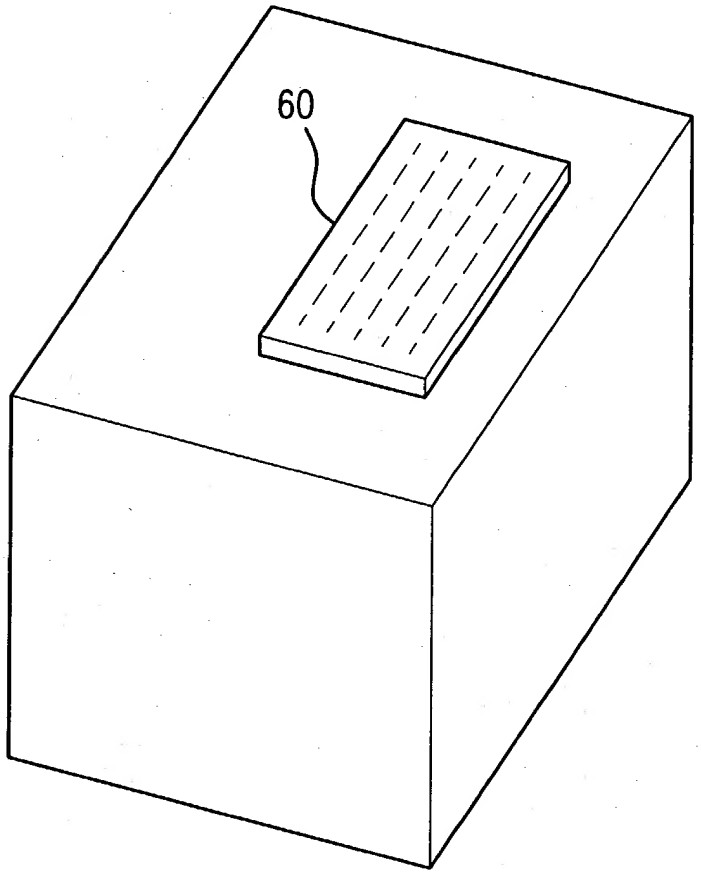


FIG.8A

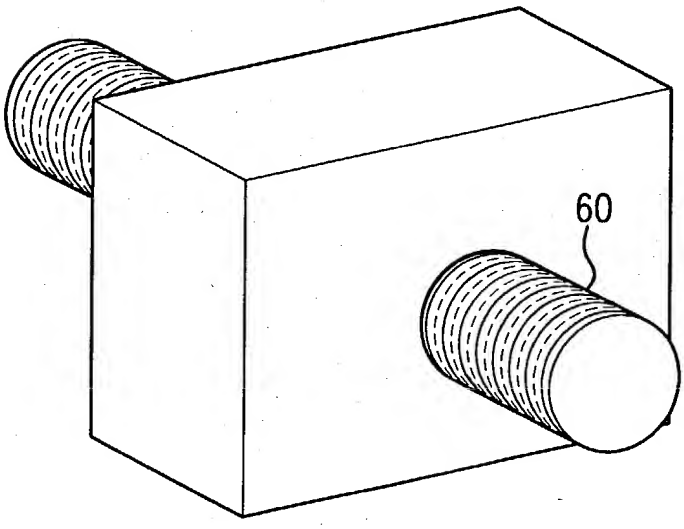


FIG.8B

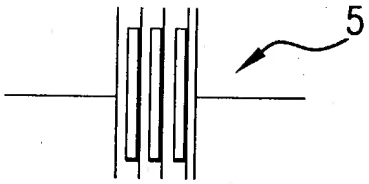


FIG.9A

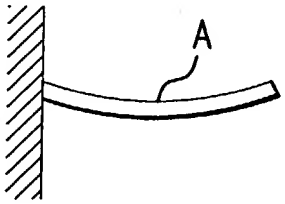


FIG.9B

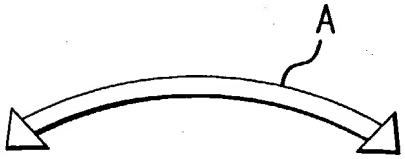


FIG.9C

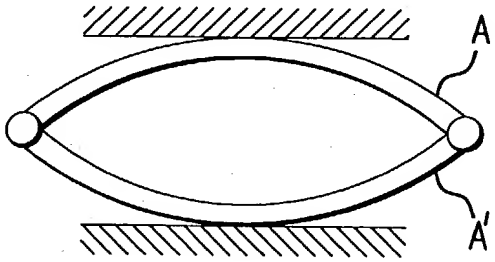


FIG.9D

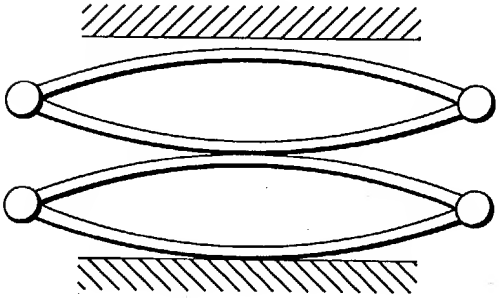


FIG.9E

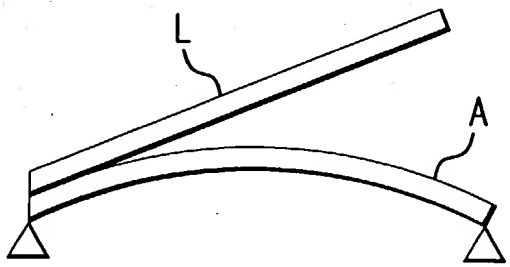


FIG.9F

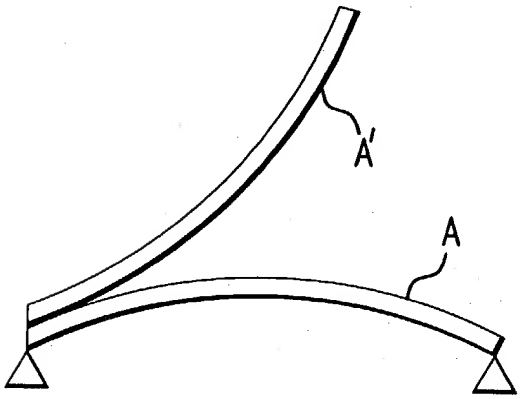


FIG.9G

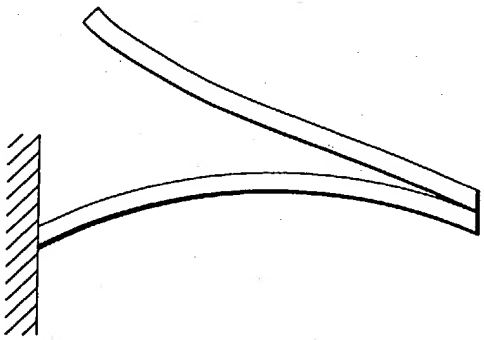


FIG.9H

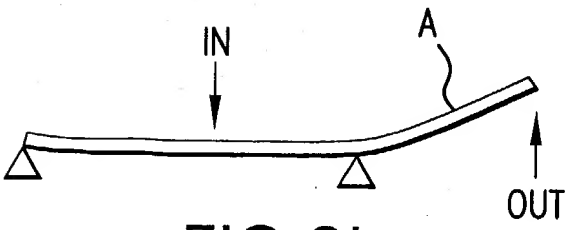


FIG.9I

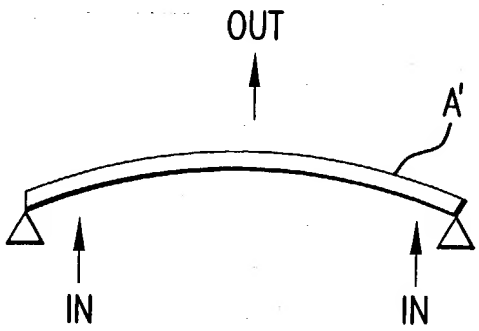


FIG.9J

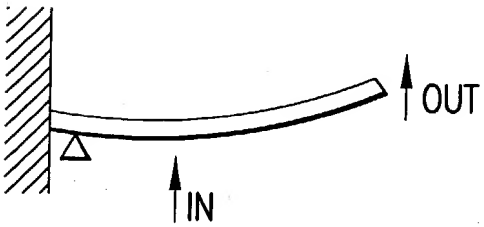


FIG.9K

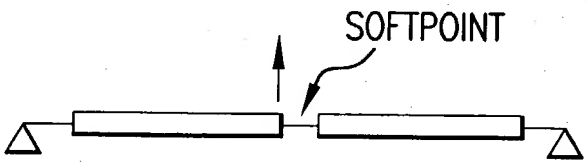


FIG.9L

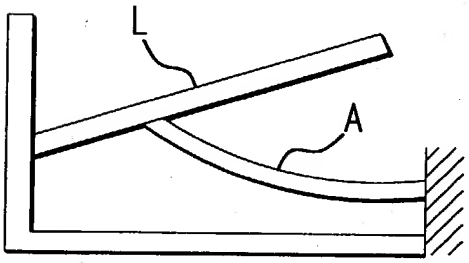


FIG.9M

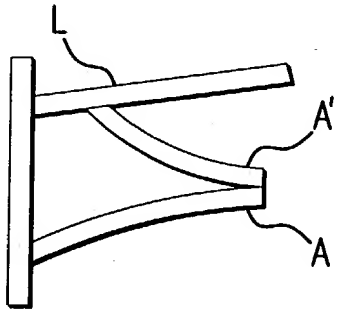


FIG.9N

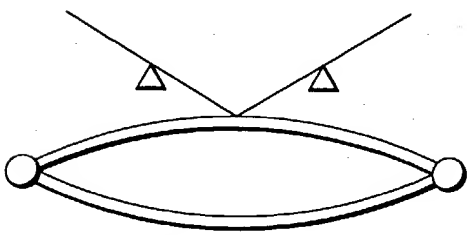


FIG.9O

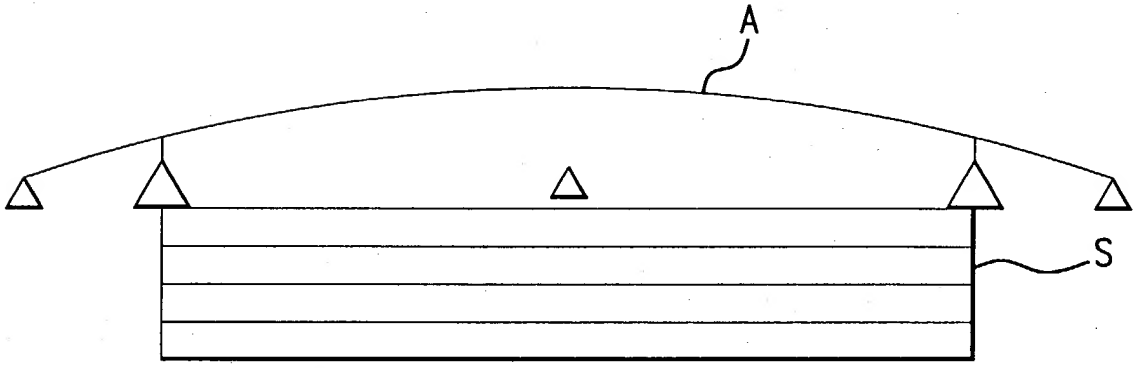


FIG.9P

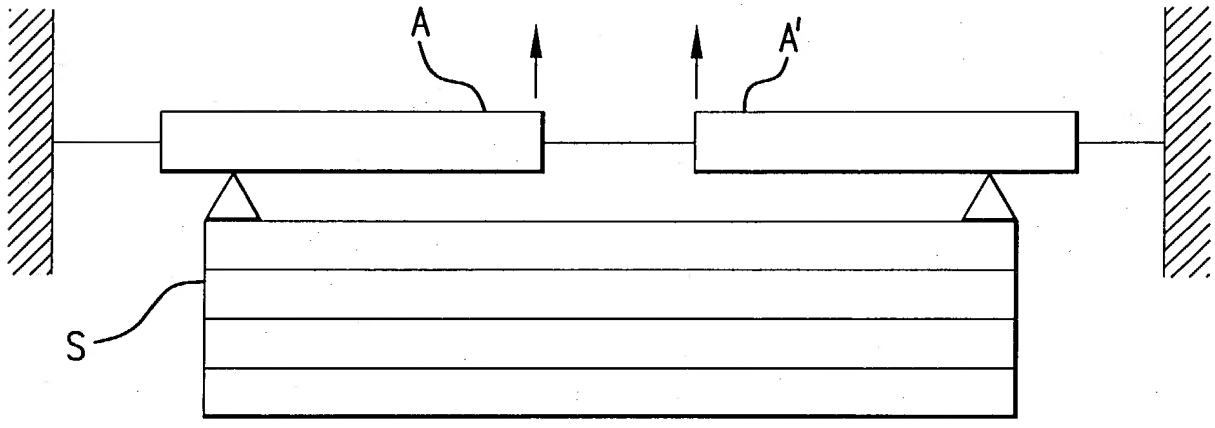


FIG.9Q

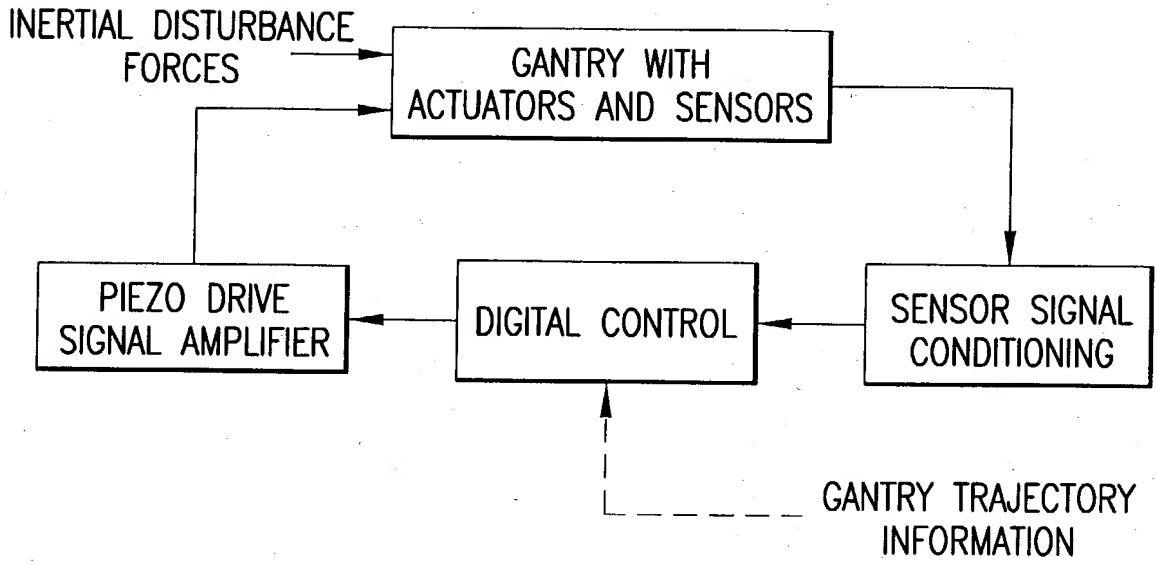

INERTIAL DISTURBANCE FORCES
GANTRY WITH ACTUATORS AND SENSORS
PIEZO DRIVE SIGNAL AMPLIFIER
DIGITAL CONTROL
SENSOR SIGNAL CONDITIONING
GANTRY TRAJECTORY INFORMATION

FIG. 10

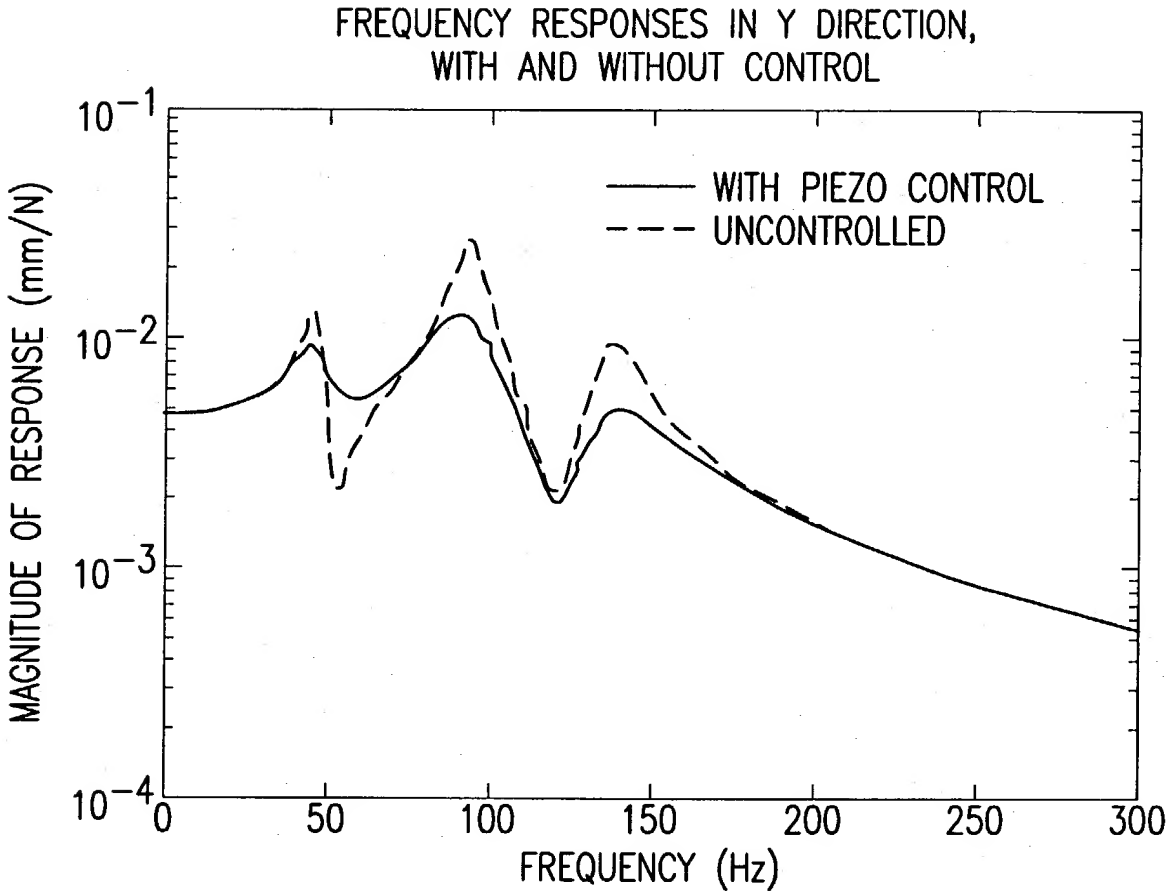

FREQUENCY RESPONSES IN Y DIRECTION,
WITH AND WITHOUT CONTROL
WITH PIEZO CONTROL
UNCONTROLLED
MAGNITUDE OF RESPONSE (mm/N)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
50
100
150
200
250
300
FREQUENCY (Hz)

FIG. 11

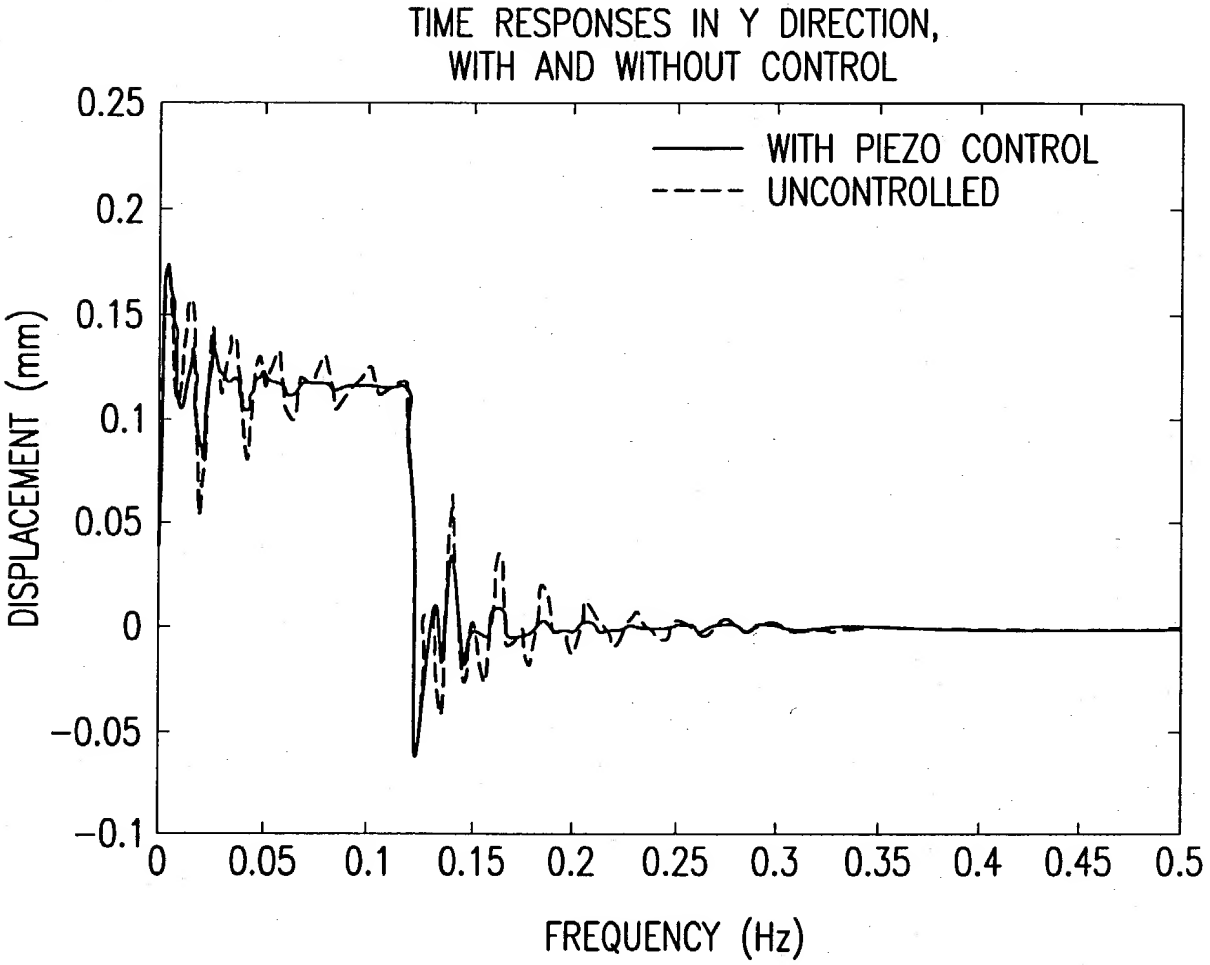

TIME RESPONSES IN Y DIRECTION,
WITH AND WITHOUT CONTROL
WITH PIEZO CONTROL
UNCONTROLLED
DISPLACEMENT (mm)
FREQUENCY (Hz)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

FIG.12

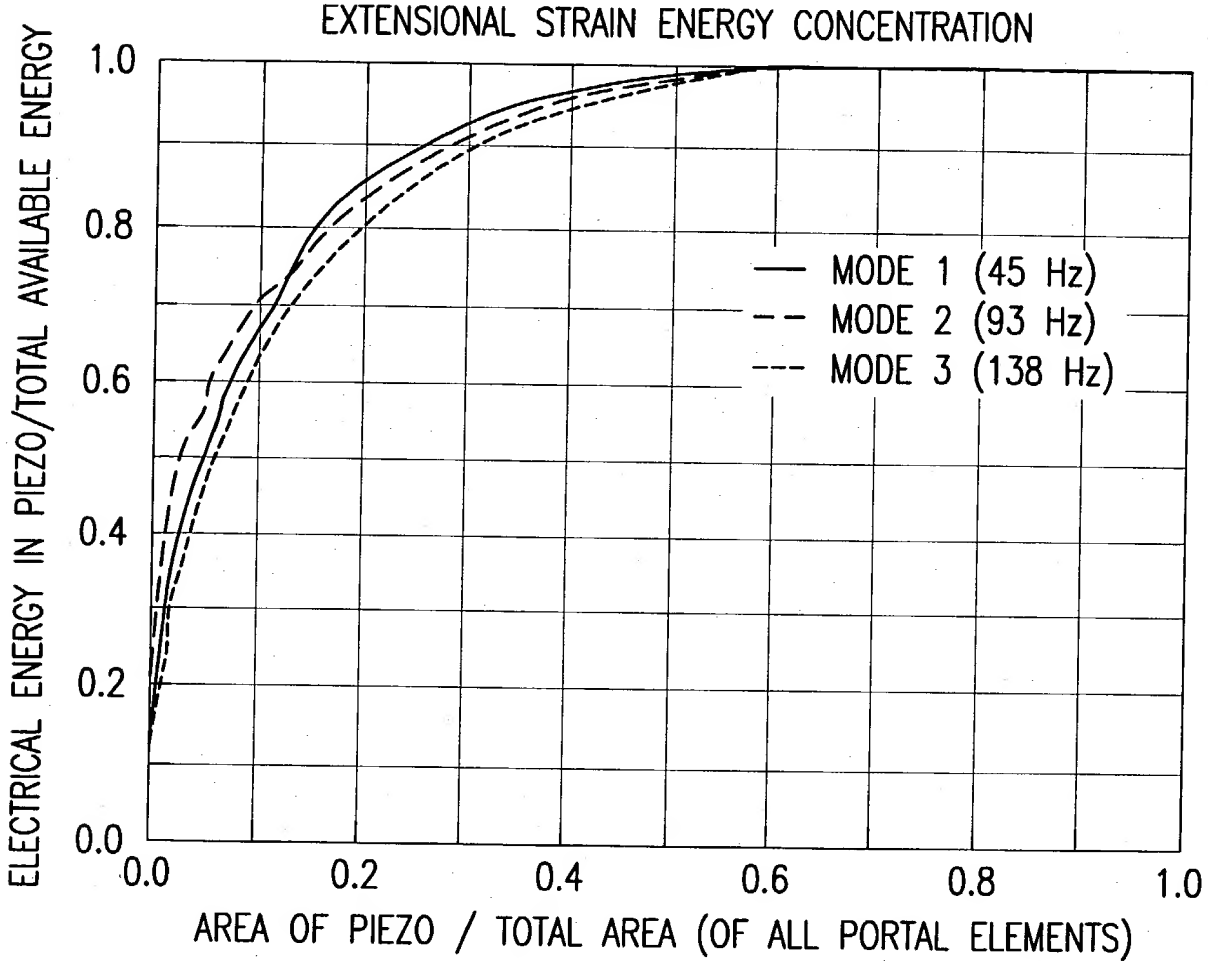

EXTENSIONAL STRAIN ENERGY CONCENTRATION
ELECTRICAL ENERGY IN PIEZO/TOTAL AVAILABLE ENERGY
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
AREA OF PIEZO / TOTAL AREA (OF ALL PORTAL ELEMENTS)
MODE 1 (45 Hz)
MODE 2 (93 Hz)
MODE 3 (138 Hz)

FIG.13

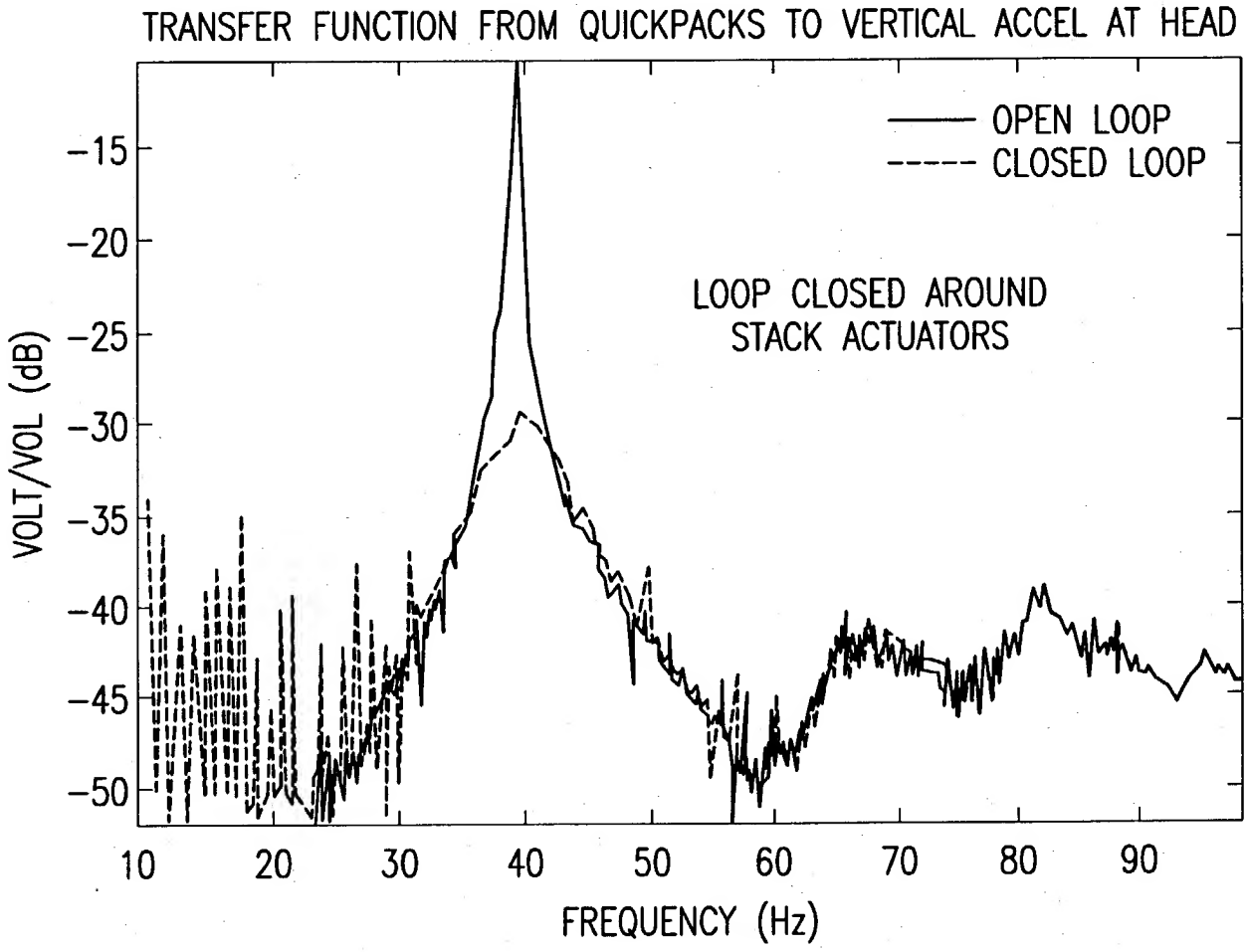

TRANSFER FUNCTION FROM QUICKPACKS TO VERTICAL ACCEL AT HEAD
OPEN LOOP
CLOSED LOOP
LOOP CLOSED AROUND
STACK ACTUATORS
VOLT/VOL (dB)
-15
-20
-25
-30
-35
-40
-45
-50
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

FIG.14

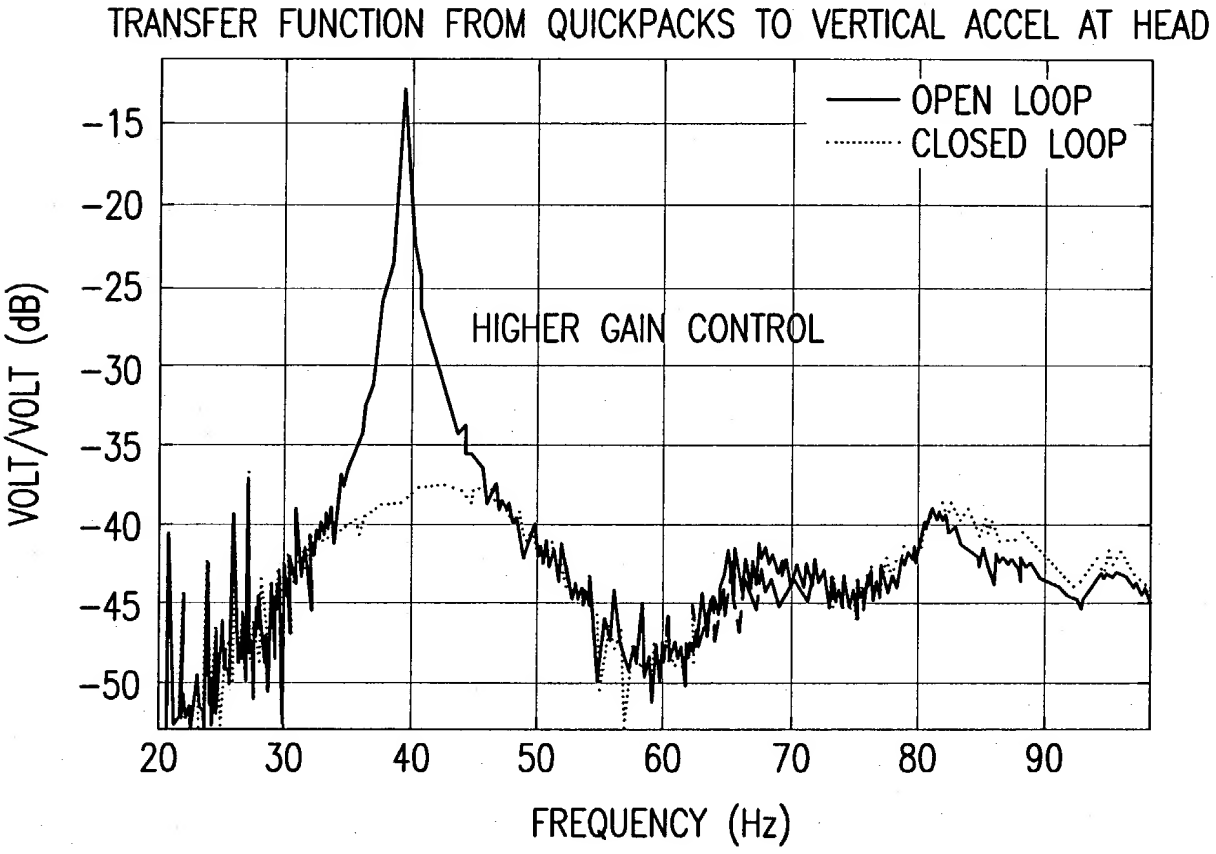

TRANSFER FUNCTION FROM QUICKPACKS TO VERTICAL ACCEL AT HEAD
OPEN LOOP
CLOSED LOOP
HIGHER GAIN CONTROL
VOLT/VOLT (dB)
-15
-20
-25
-30
-35
-40
-45
-50
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

FIG.15

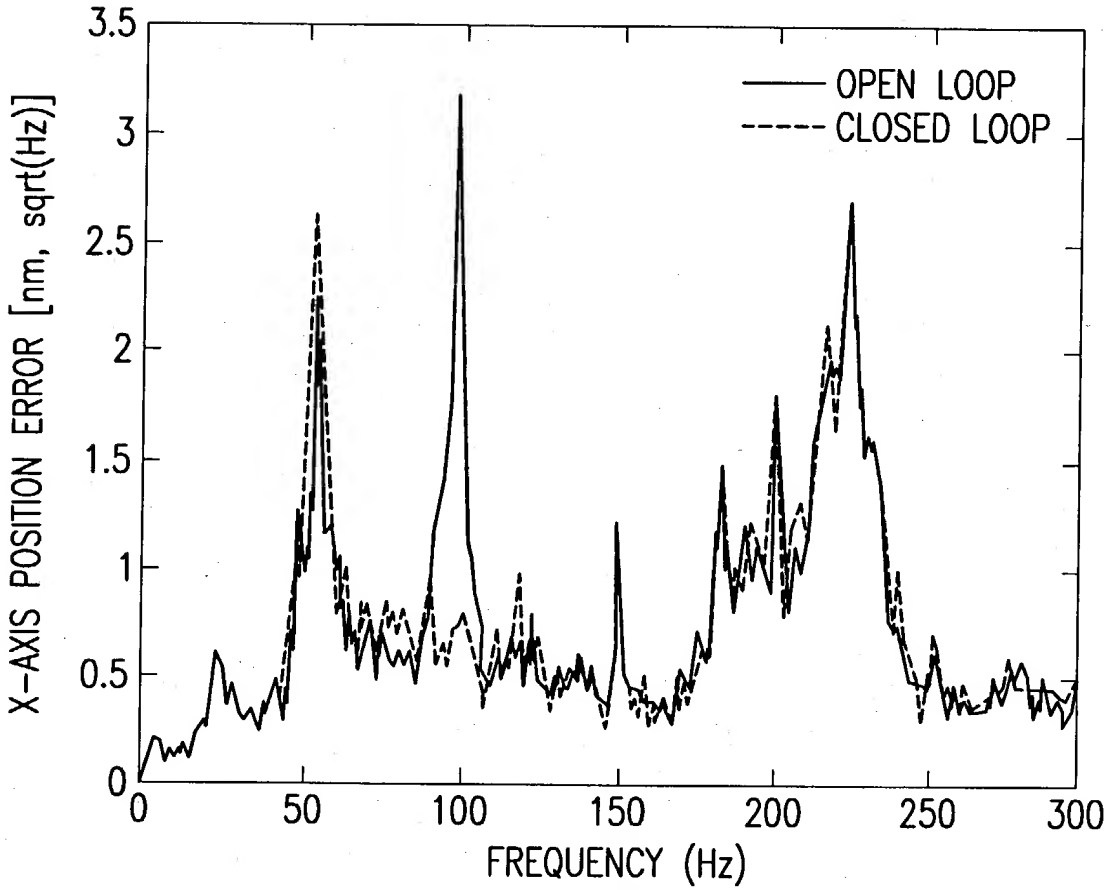

OPEN LOOP
CLOSED LOOP
X-AXIS POSITION ERROR [nm, sqrt(Hz)]
FREQUENCY (Hz)
0
0.5
1
1.5
2
2.5
3
3.5
0
50
100
150
200
250
300

FIG.16

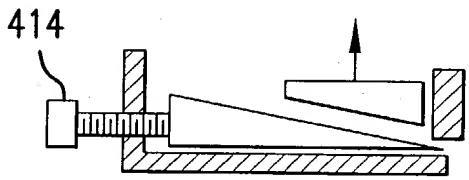


FIG.17

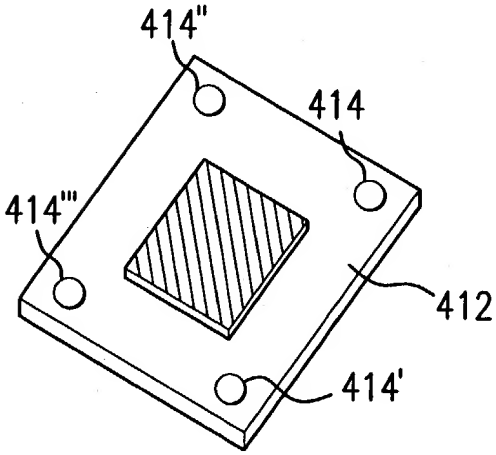


FIG.18

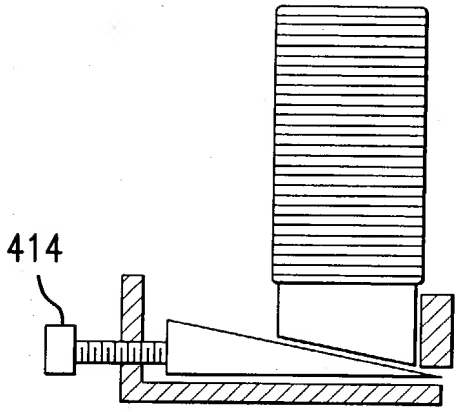


FIG.19

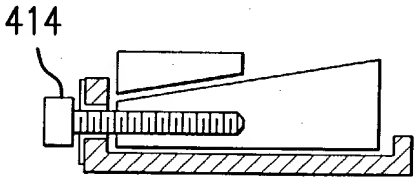


FIG.20

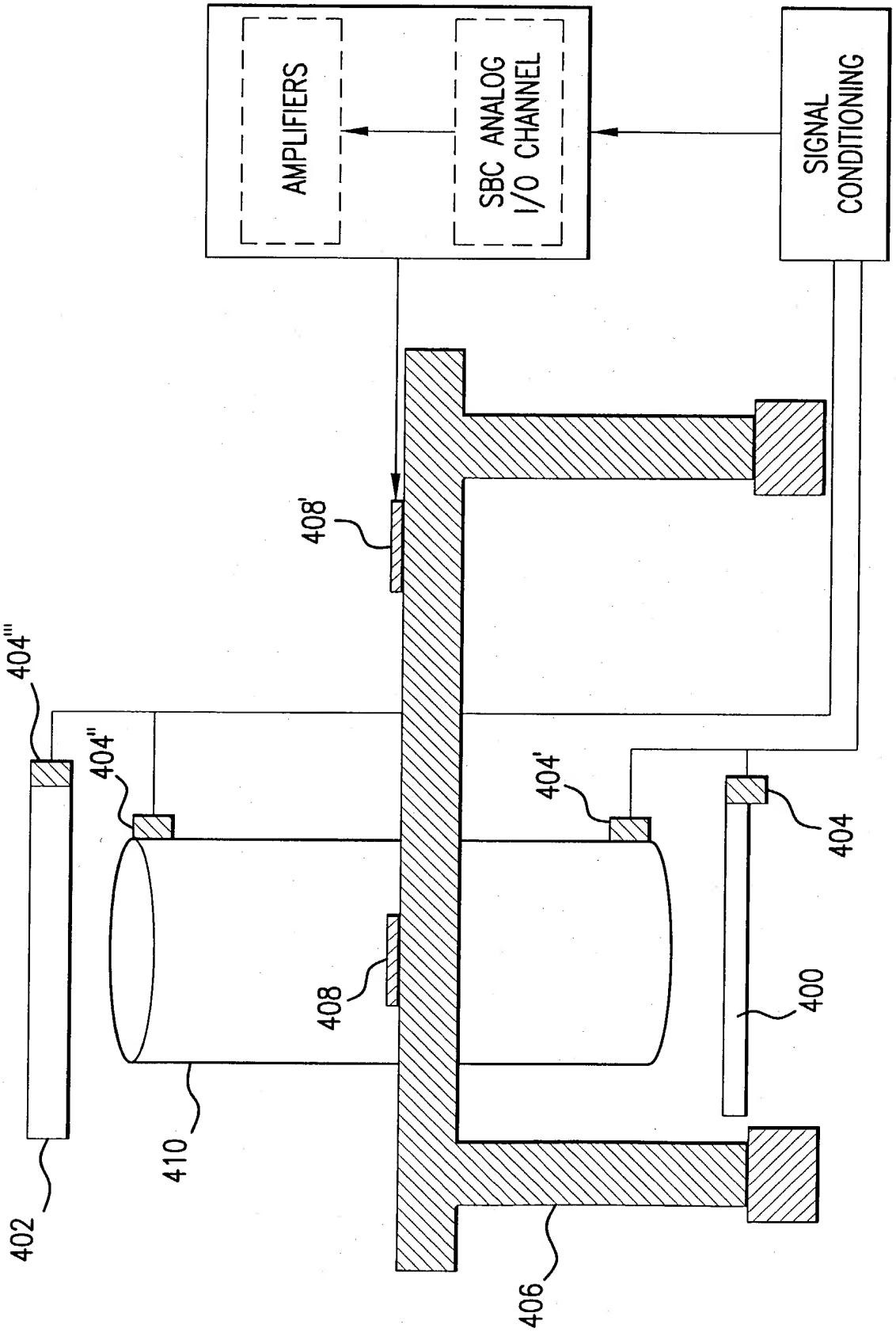
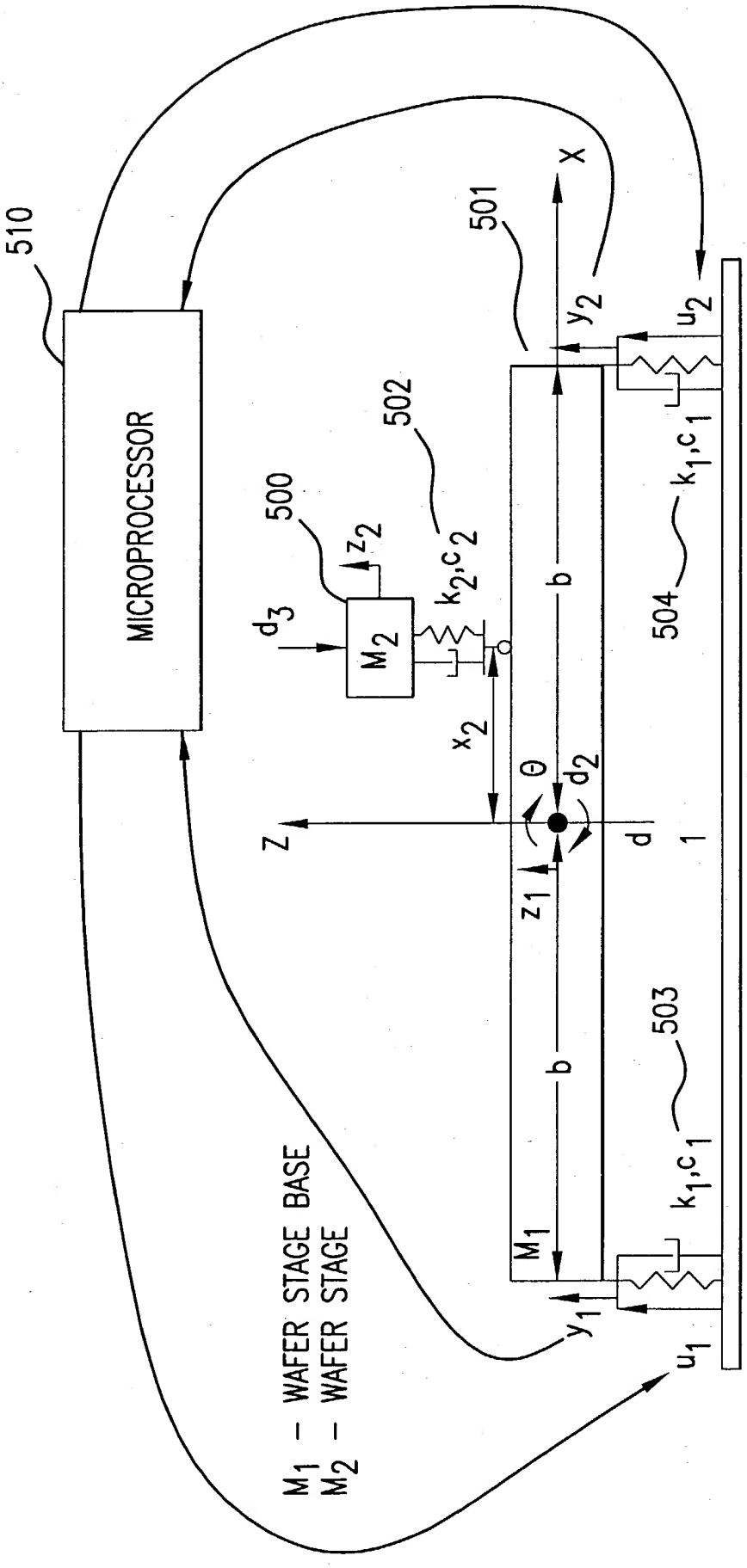

AMPLIFIERS
SBC ANALOG I/O CHANNEL
SIGNAL CONDITIONING
408'
404'''
404''
404'
404
408
400
410
402
406

FIG.21



- INPUTS (u_1): VOICE COIL FORCES ON BASE IN Z
- OUTPUTS (y_1): LASER DISPLACEMENT MEASUREMENTS COLLOCATED WITH VOICE COIL INPUTS
- DISTURBANCES (d_1): Z-FORCE AND θ MOMENT ON BASE, Z FORCE ON STAGE

FIG.22

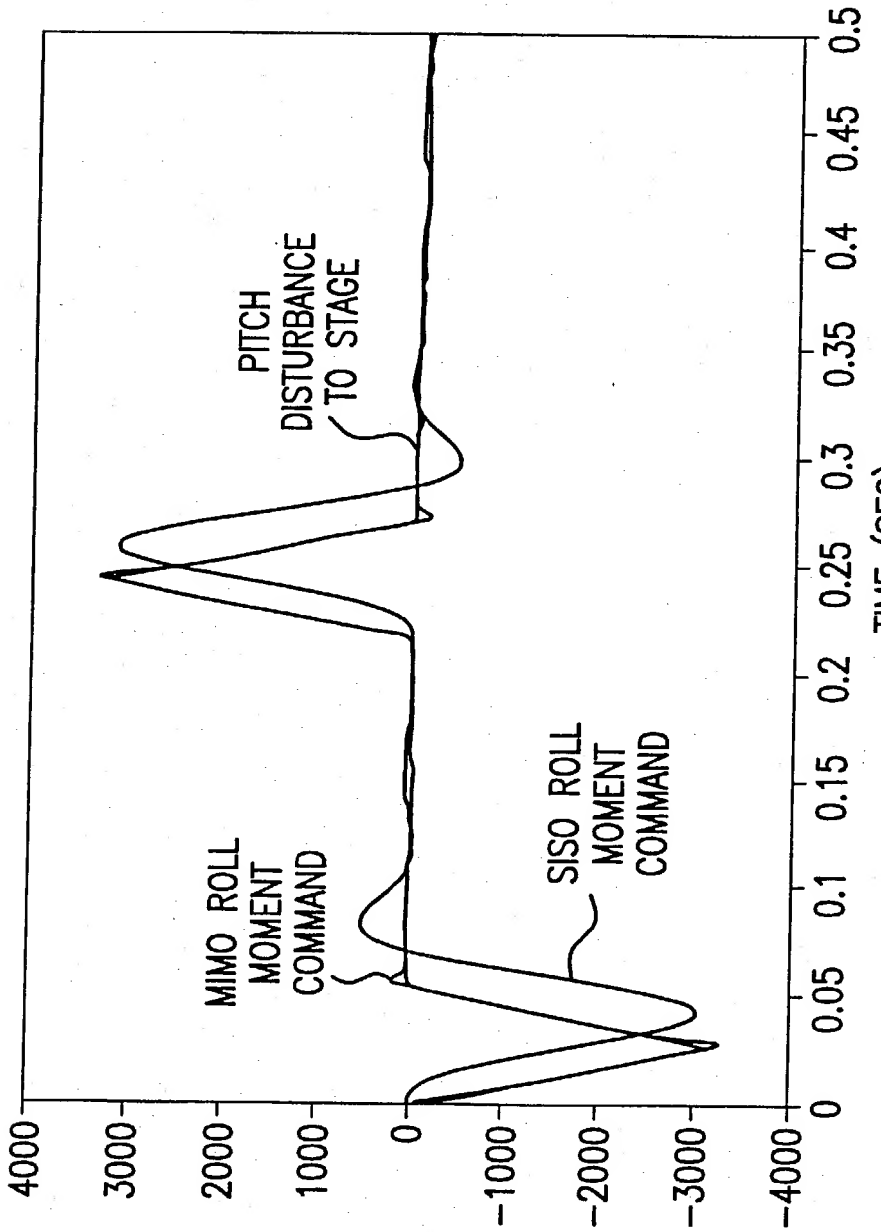

PITCH DISTURBANCE TO STAGE
MIMO ROLL MOMENT COMMAND
SISO ROLL MOMENT COMMAND
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
TIME (SEC)

FIG.23

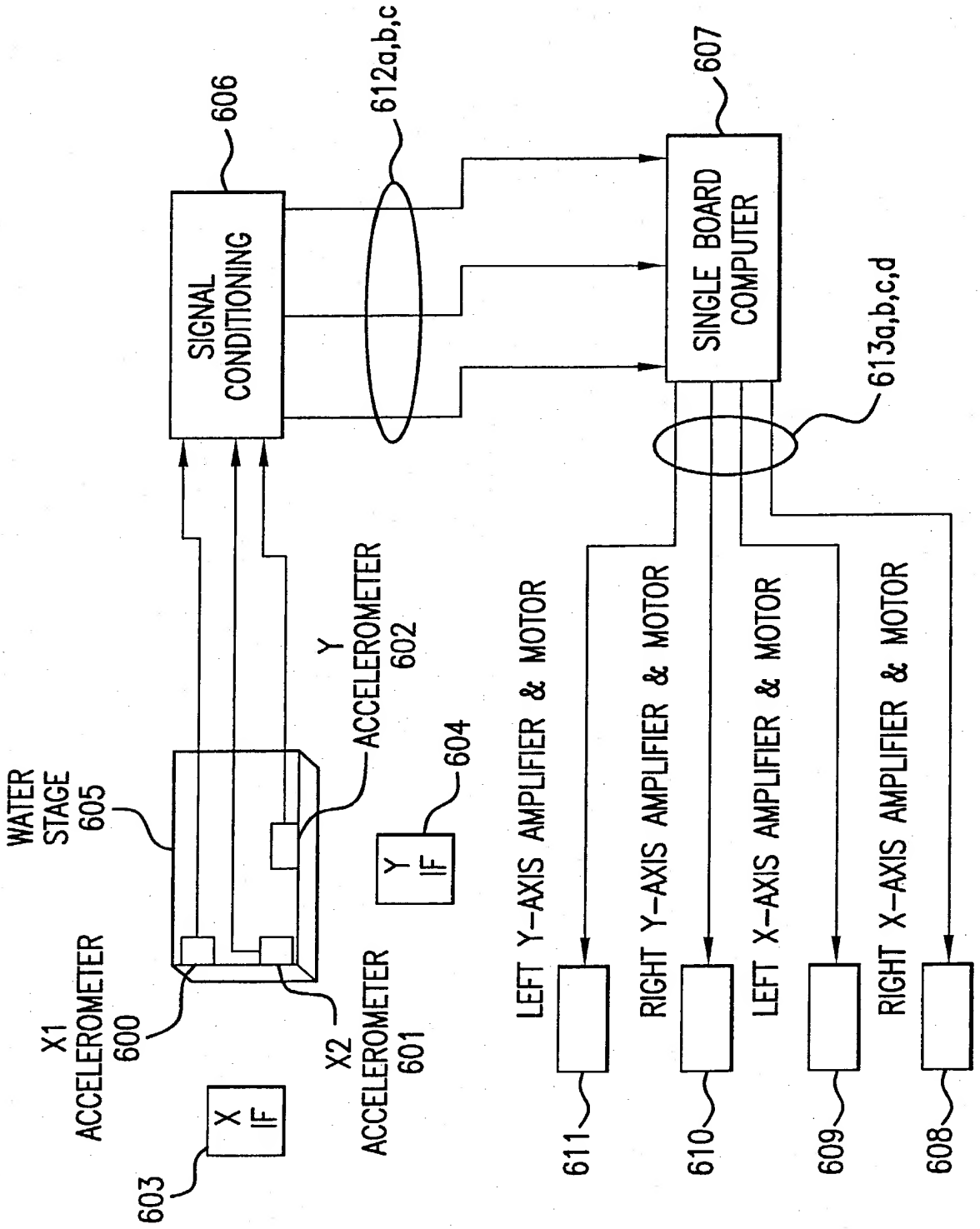

606
612a,b,c
607
SIGNAL CONDITIONING
SINGLE BOARD COMPUTER
613a,b,c,d
WATER STAGE 605
Y ACCELEROMETER 602
604
Y IF
X1 ACCELEROMETER 600
X2 ACCELEROMETER 601
X IF
603
LEFT Y-AXIS AMPLIFIER & MOTOR
RIGHT Y-AXIS AMPLIFIER & MOTOR
LEFT X-AXIS AMPLIFIER & MOTOR
RIGHT X-AXIS AMPLIFIER & MOTOR
611
610
609
608

FIG.24

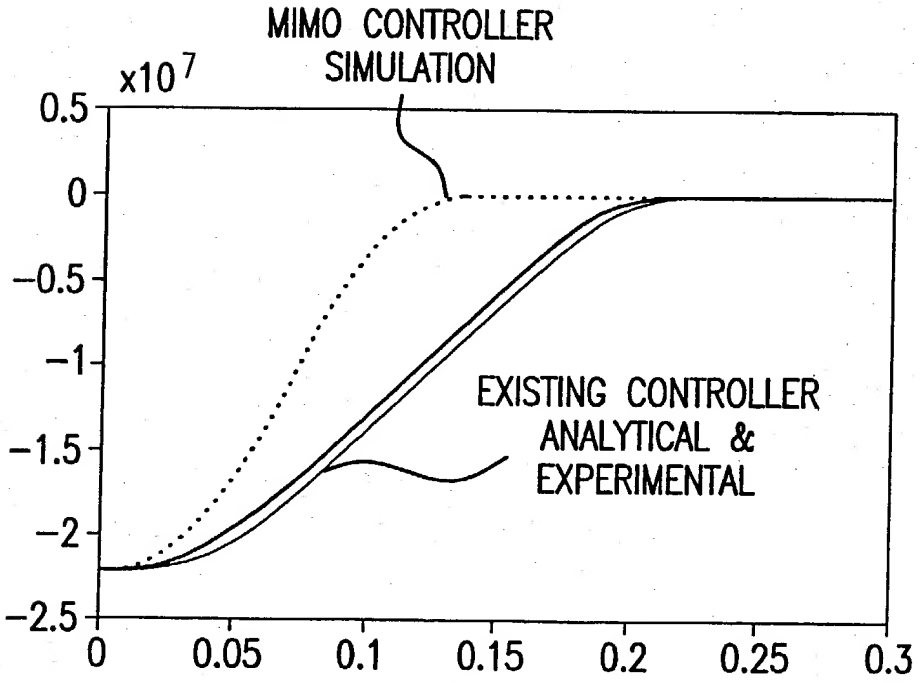

MIMO CONTROLLER SIMULATION
x10 7
0.5
0
−0.5
−1
−1.5
−2
−2.5
0
0.05
0.1
0.15
0.2
0.25
0.3
EXISTING CONTROLLER ANALYTICAL & EXPERIMENTAL

FIG. 25

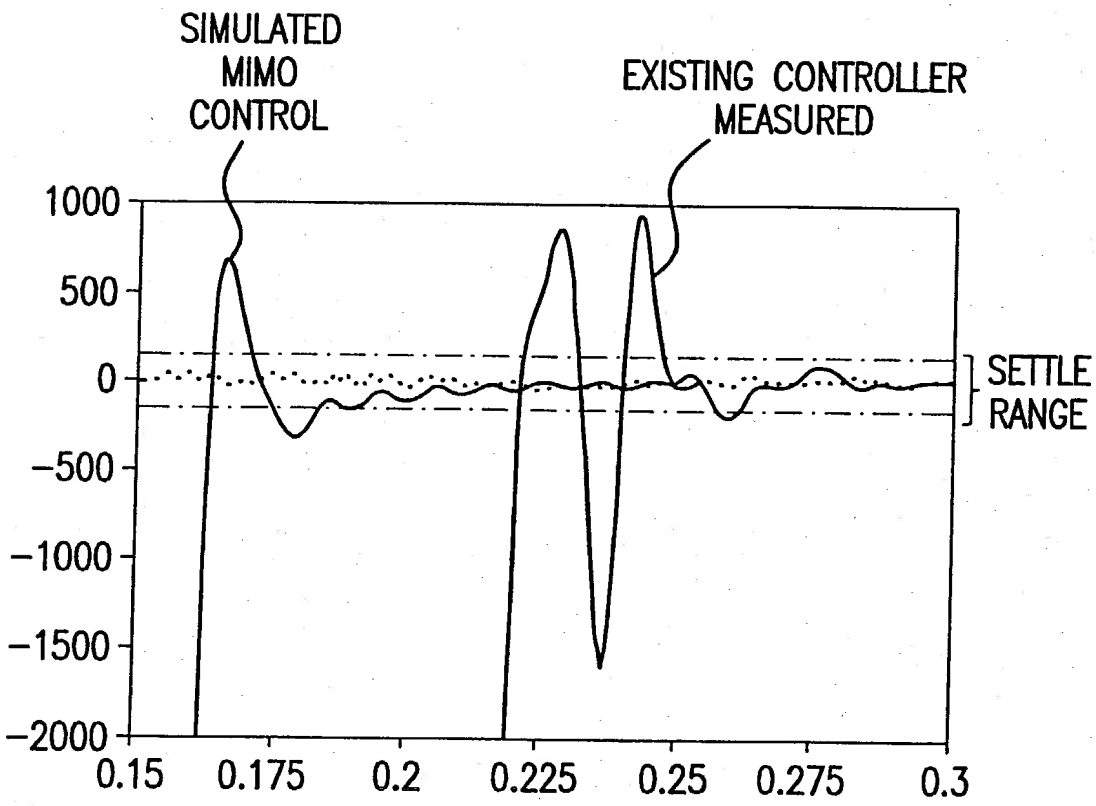

SIMULATED MIMO CONTROL
EXISTING CONTROLLER MEASURED
1000
500
0
−500
−1000
−1500
−2000
0.15
0.175
0.2
0.225
0.25
0.275
0.3
SETTLE RANGE

FIG.26